Review on investigation of "Buckling behaviour of composite plates"

Mohammed Gouse1*, Ravi kumbar .2*, T. Madhusudhan3*

1Mechanical Department, M.Tech student, Machine Design, 2Mechanical Department, Professor,

3Mechanical Department, H.O.D,

*S J B Institute of Technology, Visvesvaraya Technological University, Belagavi, Karnataka, India.

(mohdgouse20@gmail.com, Kumbarmr@gmail.com, mechhod@sjbit.edu.in)

Abstract- Composite material is one the most widely used material when strength to weight ratio is considered, this make it more ideal material in the Aerospace industries where strength to weight ratio is more important. These composite material is used to make many aircraft components like skins, rudder, fuselage and panels. Buckling behavior of laminated composite plates subjected to compressive loading is an important parameter in the preliminary design of aircraft components. This review represent the some attempts made to understand the buckling behavior of composite plates by experimental and numerical methods and various parameters which effects the buckling behavior.

Keyword: Composite material, aircraft, Woven glass/epoxy, aspect ratio, fiber orientation, Cutouts and buckling analysis with Experimental and FEA

INTRODUCTION

Composite materials have such an influence on our lives that many researches invested a great deal of time and effort for a better understanding of their behavior. Composite materials [1] have been used for a while in many industries such as: aerospace, automotive, marine and civil engineering applications one can say that composite materials usage is limited by the individual imagination.[2] One type of composite materials is cross-ply laminated plates with cutouts, where cutouts are introduced for accessibility reasons or to just lighten the structure. These plates are more explore to buckle when subjected to in plane compressive loads, therefore it is very important to under fully the various parameter which effect the buckling failure. The buckling behavior of plates has been studied by many researchers in structural mechanics for aircraft and other structural parts over a Century. Steel, Aluminium, Titanium plates are often used as the main components of aircraft structures such as fuselage, elevators, panels, skins, rudder etc. So to make optimum structural components material must possess best characteristics then other conventional materials. So composite materials are widely used for this purpose, like carbon fiber reinforced polymer (CFRP), Glass fiber reinforced polymer (GFRP), Aramide fiber reinforced polymer (AFRP), etc. There are various cutouts, vents, holes and passage are provided for different purpose, to provide access for inspection, maintenance, or simply to reduce weight. Due to this cutouts in plate components leads to change in stress distribution within the member and variations in buckling characteristics of the plate element. The effects of the shape, size, location and types of applied load on the performance and buckling behavior of such perforated plates have been investigated by several researchers over the past two decades. Many researcher explore such results for their research work.

Literature survey;

The fibers used in composite materials are glass, aramid, carbon which are synthetic fibers. The use of natural fibers is increasing due to its unique properties. They are easily available at less cost compared to synthetic fibers. Epoxies are best known for their excellent adhesion, chemical and heat resistance, mechanical properties, and outstanding electrical insulating properties. The chemical resistance of epoxies is excellent against basic solutions. Epoxies are more expensive than polyesters, and cure times are longer, but their extended range of properties can make them the cost/performance choice for critical applications. This is a best choice for products where strength and toughness are paramount, as the material offers both outstanding flexural and tensile modulus.

The following are some of the review of journal papers based on study of buckling behavior of composite plates.

I Ramu, et al,.[3] He has invested the buckling analysis of functionally graded material (FGM),by using classical plate theory. He used a FEM for modelling and buckling analysis of functionally graded material (FGM), by changing aspect ratio (a/b) of the (FGM) plates under biaxial and uniaxial compression the effective material properties are computed using the simple power law equation of the volume fraction of the plate constituents. He found that the critical buckling load of the rectangular plate under uniaxial compression is greater than the biaxial Compression and the critical buckling load increases by increasing the thickness, he also used MATHLAB for accuracy of results.

Arun kumar R,[4] has investigated Buckling Analysis of Woven Glass epoxy Laminated Composite Plate, In this study, the influence of cutout shape, length/thickness ratio, and ply orientation and aspect ratio on the buckling of woven glass epoxy laminated composite plate is examined experimentally. From the present analytical and experimental study, the following conclusions can be made. He found results, The buckling load decreases as the L/t (length to thickness) ratio of plate increases, As the aspect ratio increases, the critical buckling load of the plate decreases. When the fiber angle increases, the buckling load decreases. The reduction of the buckling load due to the presence of a cutout is found. It is noted that the presence of cutout lowers the buckling load and it varies with the cutout shape. The plate with circular cutout yielded the greatest critical buckling load.

Dr. P. Ravinder Reddy,et al.,[5] He investigated the buckling behavior of a 4-ply orthotropic carbon/epoxy symmetrically laminated rectangular composite plate under the square and rectangular cutouts and [0°/45°/45°/0°] fiber orientation and aspect ratio. Results showed that the magnitudes of the buckling loads decrease with increasing cutout positioned angle as well as c/b and d/b ratios for plates with a rectangular cutout. The magnitudes of the buckling loads of a rectangular composite plate with square/rectangular cutout decrease with increasing plate aspect ratio (a/b) and the buckling factors at various t/b ratio's such as 1/20, 1/40, 1/60, and 1/80 is investigated using ANSYS software. He concludes that the buckling factor are largely affected by aspect ratios, fiber orientation and cutout shapes.

M Mohan Kumar, et al.,[6] He investigated the buckling behavior of woven glass epoxy by varying aspect ratio (a/b), fiber orientation. By using hand layup technique he fabricated the glass epoxy planes with thickness 3mm and 6mm with the circular, square and rectangular cutouts. He used the FEA analysis using NASTRAN, and analysis of buckling behavior of aluminium plate and compared the results those with composite plate and results shows that. The buckling load decreases as the a/t ratio increases. The rate of decrease of buckling load is not uniform with the rate of increase of a/t ratio. When the aspect ratio changed from 1.0 to 1.7. The rate of change of buckling load with a/b ratio is almost uniform.

Patrick E.et al.,[7] He studied for the stiffened panel selected for the analysis, the paper shows that the three dimensional model shows a substantial increase in skin initiated buckling if the fillet is taken account. Results shows that A 5 mm radius leads to an increase of 34% increase in local buckling load performance for a skin portion of breath to thickness ratio of 100. The associated overall buckling load increases by 1.8%. The mass penalty for a 5 mm radius is 5.1%. To avoid local and overall buckling interaction an accurate measure of both buckling loads is very important and may have impact for designers. The three dimensional models with no fillets show very good agreement with the two dimensional models.

X. L. Xue, et al.,[8] research on process of buckling of thin compressed films deposited on polymethylmethacrylate (PMMA) substrates under mechanical and thermal loadings has been investigated utilizing an optical microscope. Particularly, thermal cycling analysis on thin film/substrate system under compression has been characterized to discuss the thermal fatigue property of aluminum film on PMMA substrate This study reveals that thermal cycling of films may cause horizontal cracks on the buckles of aluminum film. Thermal stresses T play a key role on the membrane deformation and damage.

Husam Al Qablan et al,.[9] has studied the effect of various parameters on the buckling load of square cross-ply laminated plates with circular cutouts and three types of in-plane loading considered namely, uniaxial compression, biaxial compression and shear loading. He found for relatively small size cutouts, a better performance was achieved if the cutout is kept close to the edge of the plate, however, for relatively large size cutouts, a higher buckling load is achieved if the cutout is kept in the middle of the plate. The best performance was achieved by [45,-45] fiber orientation and the worst was observed in the [0, 90] fiber orientation.

Murat Yazici [10] studied the influence of square cut-out upon the buckling stability of multilayered, steel woven fiber-reinforced polypropylene thermoplastic matrix composite plates are studied by using numerical and experimental methods. The laminated plates under uniform pressure are formed by stacking three composite layers bonded symmetrically. The FE and experimental results are presented for various fiber orientation angles and plate boundary conditions.

Buket Okutan Baba [11] studied the influence of boundary conditions on the buckling load for rectangular plates. Boundary conditions consisting of clamped, pinned, and their combinations are considered. Numerical and experimental studies are conducted to investigate the effect of boundary conditions, length/thickness ratio, and ply orientation on the buckling behaviour of E-glass/epoxy composite plates under in-plane compression load. Buckling analysis of the laminated composites is performed by using finite element analysis software ANSYS. Tests have been carried out on laminated composites with circular and semicircular cut-outs under various boundary conditions. Comparisons are made between the test results and predictions based on finite element analysis.

Zahari and Azmee [12] a progressive failure analysis algorithm has been developed by and implemented as a user subroutine in a finite element code (ABAQUS) in order to model the non-linear material behavior and to capture the complete compressive response of woven composite plates made of glass-epoxy material. Tsai-Hill failure theory has been employed in the progressive failure methodology to detect failure of the woven composite laminates.

A. Ghorbanpour Arani, et al,.[13] has studied the buckling analysis of laminated composite plates reinforced by single-walled carbon nanotubes (SWCNTs) is carried out using an analytical approach as well as the finite element method. The critical buckling loads for the symmetrical layup are determined for different support edges, The Mori-Tanaka method is employed to calculate the effective elastic modulus of composites having aligned oriented straight nanotubes. The results show that the critical buckling load obtained from FEM is in good agreement with those obtained by the analytical solution. For all of the boundary conditions considered, the aspect ratio of a /b = 2 and the orientation angle of 45 yield the highest critical buckling load.

s.j. guo[14] has investigated the effect of reinforcements around the cutout stress concentration and buckling behavior of carbon/epoxy under in plane compressive loading. He made a four sample; un-reinforcement cutout, single composite ring reinforcement, double composite ring and double steel ring. All are performed in plane compressive loads and experimental results are compared with FEA analysis and results shows that the, reinforcement type 1 is most effective for metallic shear planes and sample 2 & 3 shows the for small and medium sized cutouts metallic panels more effective then composite and sample 4 is best for composite shear panels.

Results

Glass/epoxy composite plates, maximum buckling load for different parameters.

Experiment	Different parameters	Buckling load Expt, (KN)	ANSYS
(L/t) ratio	34%	33.4	34
Aspect ratio	50%	25.2	27
Fiber orientation	0°	23	23.5
Cutout shapes	circular	24.5	25.75

ACKNOWLEDGMENT

I would like to thank my parents to support and to praise me during this work, by their support I am able to stand at today’s position. I am very glade to thank my dissertation supervisor, Professor Anil kumar G and Professor Ravi Kumbar, Dept of mechanical engg. SJBIT Bangalore. They has led me into the area of research where I have growing interests. Their expertise, vision and diligence coupled with his flexibility and patience has formed the excellent tailored guidance needed for this work and the preparation of this paper. I would also thankful to all my friends who encourage me a lot for study as well as life purpose. For all those I am most grateful.

CONCLUSION

The review shows that there is lot of research work going on buckling analysis of composite plates to understand the various parameters to avoid failure of composite materials under compressive loading. The following may be concluded based on review.

1. Buckling load decreases with the introduction of cutouts.
2. Buckling strength shows decreases with the rectangular cutouts and shows high for circular holes
3. Buckling strength is more for 45 in compares to 90 for fiber orientation.
4. Buckling strength is more if the cutouts are near the plate edges.
5. Critical buckling load of the rectangular plate under uniaxial compression is greater than the biaxial Compression and the critical buckling load increases by increasing the thickness.

6. Straining rate of 1.3mm is give more accurate results.

Based on above conclusion, its noticed that study of buckling behavior of hybrid composite plates is very limited, therefore it's important to understand the buckling behavior of hybrid composite plates which as a wide applications in aerospace, automobiles, civil engineering etc.

REFERENCES:

1] Mudhujit Mokhopadhyay," mechanics of composite materials and structures". university press,2008,2009.2012,2013.

[2] "Maya JACOB JOHN CSIR Materials Science and Manufacturing",2000.

[3] Arun kumar R , . "Buckling Analysis of Woven Glass epoxy Laminated Composite Plate", 2014; 2(3): 35-42 Published online June 10, 2014

[4] I Ramu and S.C. Mohanty "Buckling Analysis of Rectangular Functionally Graded Material Plates under Uniaxial and Biaxial Compression Load" 1877-7058 © 2014 The Authors. Published by Elsevier Ltd.

[5] Dr. P. Ravinder Reddy1,et al.,," Buckling Analysis of Orthotropic Laminated Composite Plate With Rectangular Cut-Outs By Using FEA" IJETCAS 14-719; © 2014, IJETCAS

[6] M Mohan Kumar, et al.,[6]. "Buckling Analysis of Woven Glass Epoxy Laminated Composite Plate." (AJER) e-ISSN :2320-0847 p-ISSN : 2320-0936 Volume-02, Issue-07, pp-33-40

[7] Patrick E.et al,. FEA buckling analysis of stiffed plates with filleted junctions 0263-8231 & 2012 Elsevier Ltd.

[8] X. L. Xue, et al.,"Experimental Investigation on Buckling of Thin Films in Mechanical-Thermal Coupled-Field"1875-3892 © 2011 Published by Elsevier B.V.

[9] Husam Al Qablan et al,.."Assessment of the Buckling Behavior of Square Composite Plates with Circular Cutout Subjected to In-Plane Shear" Jordan Journal of Civil Engineering, Volume 3, No. 2, 2009

[10] Murat Yazici ," buckling analysis of woven glass epoxy by changing orientations experimental and FEA " in year 2012

[11] Buket Okutan Baba "investigating of buckling behavior of woven glass epoxy under in plane compressive loads" issn in year 2011

[12] Zahari and Azmee,. "progressive failure analysis to capture the complete compressive response of woven composite plates made of glass-epoxy material" International Journal of Engineering and Technology, Vol. 4, No. 2, 2007, pp.260-265

[13] A. Ghorbanpour Arani, et al,." Buckling analysis of laminated composite rectangular plates reinforced by SWCNTs using analytical and finite element methods" KSME & Springer 2011.

[14] S.j. guo "Stress concentration and buckling behavior shear loaded composite panels with reinforcement cutouts" composite structure (80) 2007 1-9